Novel mode hop free chirped laser

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ABSTRACT

This paper related to a single mode laser source tunable in wavelength by a relatively rotating etalon wherein the cavity length is optimized for maximizing the mode hop free tuning range by matching the second order coefficients describing the relative change in the optical path length of the laser cavity and the relative change in the pass band of the etalon. The laser comprises of a lasing gain medium with at least one of its output facet anti-reflected coated, collimating optics, a relatively rotatable etalon and at least one relatively rotatable mirror.

Keywords: diode lasers, external cavity, etalon,

1. INTRODUCTION

Frequency chirped lasers for use in interferometry and other scientific instruments are known. In particular it is known that Littrow and Littman-Metcalf configured external cavity semi-conductor are such devices [1-5]. Currently available commercial systems are based upon rotating diffraction gratings. By rotating the diffraction grating about a known point is possible to increase the external cavity length in harmony with the retro-reflected diffracted light such that the external laser cavity frequency keeps in synchrony with the diffracted light. If this is not the case then the laser will mode hop. Sacher Lasertechnik has filed patents about describing the position of this key point. The use of diffraction gratings has two disadvantages. Firstly, it needs a well defined point of rotation. Translation of the point during rotation of greater than $\lambda/2$ guarantees a mode hop. Secondly, tilt of the diffraction grating causes angular misalignment resulting in reduced coupling efficiency between the external cavity and the gain medium (laser diode). This can be mitigated by the use of a plano-convex lens that focuses the light as a line along the diffraction grating. These constraints imply cost.

In this paper, we use an optic which to first approximation can translate or wobble without inducing a mode hop. The optic is a rotating glass block. As the block rotates it causes the external cavity optical path length to change. To ensure that only one longitudinal mode from lasing we use a co-rotating etalon. The angular orientation of the etalon is chosen to maximize the mode hop free tuning range. In practice the co-rotating etalon is embedded inside the glass block so as to produce a single robust "glass block".

2. THE EXTERNAL CAVITY DESIGAN

In order to investigate the length change of an external laser cavity, etalon embedded inside the glass block is introduced shown in Figure 1. The end mirror is perpendicular to the incident laser beam. The rotating glass block is placed between the gain medium and the end mirror. The etalon is coated both sides with a reflectivity of about 95%. The thickness of etalon was chosen to give a free spectral range about 1nm. A narrowband pass filter is inserted between glass block and mirror to control the laser longitudinal modes outside of the free spectral rang of the etalon. By using combination the etalon and filter will only allow only one lasing longitudinal mode. We investigated the length changes as a function of angle of the external cavity and see how will they match with the optical properties of a co-rotating glass block with an embedded etalon.

Let L be the optical cavity length of the external cavity excluding the refractivity of the glass block at normal incidence. This means that L includes the optical length of the gain medium, lenses and filters shown in Figure 1. Let the length of the glass block be *l*. Then for normal incidence the optical length of the cavity is:

$$L+(n-1)*l \tag{1}$$

where n is the refractive index of the glass block.

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If the glass block is at an angle θ, then the displaced air path for the block is no longer l, but

$$l * \frac{Cos(\theta - \theta_1)}{Cos(\theta_1)} \tag{2}$$

The optical path length through the block is:

$$n * l / Cos(\theta_1) \tag{3}$$

Thus the optical path length for the cavity is now:

$$L - \frac{l * Cos(\theta - \theta_1)}{Cos(\theta_1)} + n * l / Cos(\theta_1) \tag{4}$$

The optical path length through the etalon is given by:

$$2n * d * Cos(\theta_2) \tag{5}$$

where θ_2 is the internal angle inside the etalon. In Figure 1, it is shown as the angle of incidence onto the etalon but this is only valid because the etalon is made of the same material as the glass block.

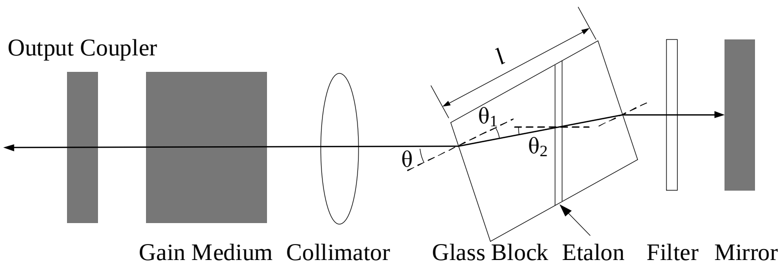

Figure 1. The external cavity design for mode hop free chirped laser

3. RESULTS AND ANALYSIS

Figure 2 and Figure 3 show the optical cavity length and etalon optical thickness versus the angle of incidence, respectively by the equations (1-5). Ideally these two curves should match each other. This implies that as the angle of incidence onto the glass block increases the angle of incidence onto the etalon must decrease.

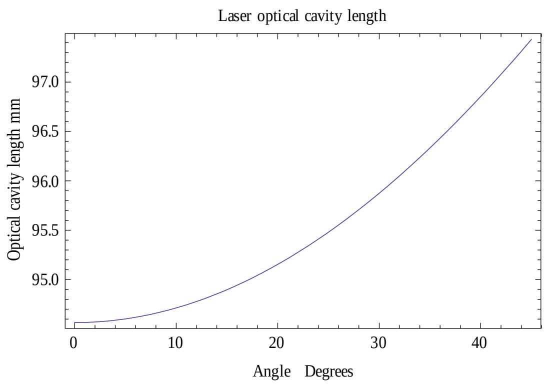

Figure 2. The optical cavity length versus the angle of incidence.

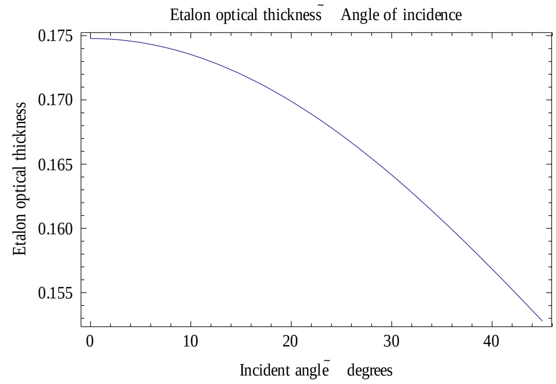

Figure 3. The Etalon optical thickness versus the angle of incidence.

For mode hop free operation the ratio of the path length change in the external cavity to its nominal length needs to match the ratio of the path length change through the etalon to its nominal length to within a limit.
When we consider the etalon firstly, by choosing an appropriate centre angle and taking the ratio of them produces the following Figure 4. Similarly considering for the laser cavity optical length, Figure 5 shows the fractional change in cavity length versus the angle of incidence.

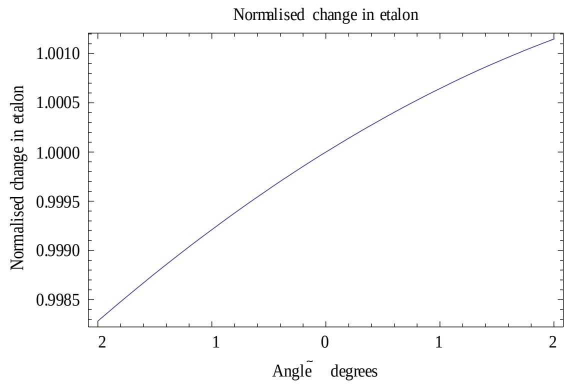

Figure 4. Normalized change in etalon versus the angle of incidence

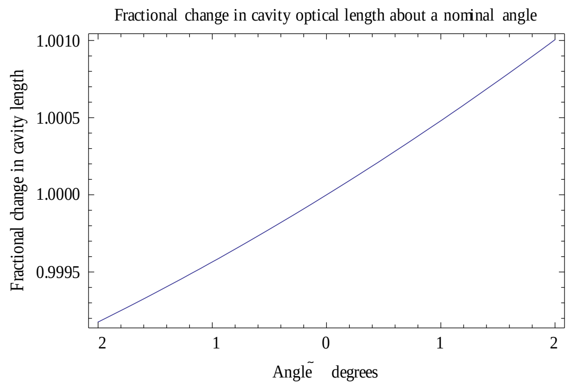

Figure 5. Fractional change in cavity length versus the angle of incidence

By embedding the etalon inside the glass block one can obtain the following Figure 6. Since this is a laser cavity an optical path length difference of greater than $\lambda/4$ will result in a mode hop. Thus at 650 nm if the path length difference exceeds 161.5 nm the cavity will jump to the next longitudinal mode. Thus for a cavity having an optical path length of 60 mm this will occur when the fractional difference is $\sim 2.7*10^{-6}$. Thus in principle one should obtain a wavelength chirp of about 0.0035 nm or 250 GHz.

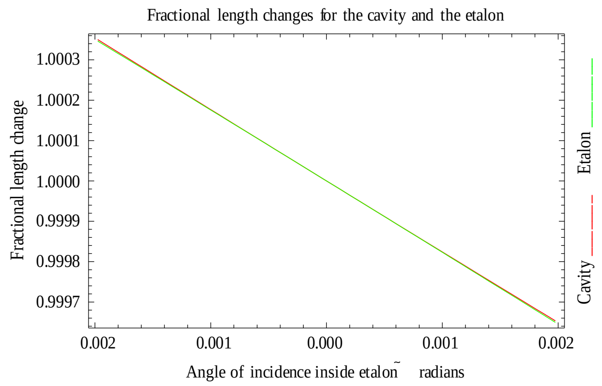

Figure 6. Fractional length change versus the angle of incidence inside etalon

4. CONCLUSION

A theoretical tuning range for a novel method for altering the optical cavity length in an external laser diode cavity has been shown. A theoretical tuning range in excess of 100 GHz has been obtained. The advantage of the design is that the rotating glass block is free to translate without causing a frequency error or mode hop. The limitation of the design is the maximum angle of incidence one can use and etalon and still obtain reasonable suppression of the adjacent longitudinal modes to prevent mode hops and how well matched are the path length changes in the external cavity and the path length change of the etalon.

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